

# Inverse Split Edge Domination in Fuzzy Graphs

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**Abstract.** In this paper we discuss the concepts of inverse split edge domination and total edge domination in fuzzy graph. We determine the inverse split edge domination number  $\gamma'_{IS}(G)$  and the total edge domination number  $\gamma'_t(G)$  for several classes of fuzzy graph and obtain bounds for the same. We also obtain Nordhaus – Gaddum type results for these parameters.

**Keywords:** Fuzzy graph; Edge domination; Inverse split edge domination; Total edge Domination.

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## 1. INTRODUCTION

The study of domination set in graphs was begun by Ore and Berge. Rosenfield introduced the notion of fuzzy graph and several fuzzy analogs of graph theoretic concepts such as paths, cycles and connectedness. A.Somasundram and S.Somasundram discussed domination in Fuzzy graphs. V.R. Kulli and D.K. Patwari discussed the total edge domination number of graph. They defined domination using effective edges in fuzzy graph. In this paper we discuss the inverse split edge domination number of fuzzy graph using fuzzy edge cardinality and establish the relationship with other parameter which is also investigated.

## 2. PRELIMINARIES

### Definition 2.1

A fuzzy graph  $G = (\sigma, \mu)$  is a set with two functions,  $\sigma : V \rightarrow [0,1]$  and  $\mu : E \rightarrow [0,1]$  such that  $\mu(xy) \leq \sigma(x) \wedge \sigma(y) \forall x, y \in V$ .

### Definition 2.2

Let  $\mu = (\sigma, \mu)$  be a fuzzy graph on  $V$  and  $V_1 \subseteq V$ . Define  $\sigma_1$  on  $V_1$  by  $\sigma_1(x) = \sigma(x)$  for all  $x \in V_1$  and  $\mu_1$  on the collection  $E_1$  of two element subsets of  $V_1$  by  $\mu_1(xy) = \mu(xy)$  for all  $x, y \in V_1$ . Then  $(\sigma_1, \mu_1)$  is called the fuzzy subgraph of  $G$  induced by  $V_1$  and is denoted by  $\langle V_1 \rangle$ .

### Definition 2.3

The order  $p$  and size  $q$  of a fuzzy graph  $G = (\sigma, \mu)$  are defined to be  $p = \sum_{x \in V} \sigma(x)$  and  $q = \sum_{xy \in E} \mu(xy)$ .

### Definition 2.4

Let  $\sigma : V \rightarrow [0,1]$  be a fuzzy subset of  $V$  then the complete fuzzy graph on  $\sigma$  is defined on  $G = (\sigma, \mu)$  where  $\mu(xy) = \sigma(x) \wedge \sigma(y)$  for all  $xy \in E$  and is denoted by  $K_\sigma$ .

**Definition 2.5**

The complement of a fuzzy graph  $G$  denoted by  $\bar{G}$  is defined to be

$$\bar{G} = (\sigma, \bar{\mu}) \text{ where } \bar{\mu}(xy) = \sigma(x) \wedge \sigma(y) - \mu(xy).$$

**Definition 2.6**

Let  $G = (\sigma, \mu)$  be a fuzzy graph on  $V$  and  $S \subseteq V$ . Then the fuzzy cardinality of  $S$  is defined to be  $\sum_{v \in S} \sigma(v)$ .

**Definition 2.7**

Let  $G = (\sigma, \mu)$  be a fuzzy graph on  $E$  and  $D \subseteq E$  then the fuzzy edge cardinality of  $D$  is defined to be  $\sum_{e \in D} \mu(e)$ .

**Definition 2.8**

An edge  $e = xy$  of a fuzzy graph is called an effective edge if  $\mu(xy) = \sigma(x) \wedge \sigma(y)$ .  $N(x) = \{y \in V \mid \mu(xy) = \sigma(x) \wedge \sigma(y)\}$  is called the neighbourhood of  $x$  and  $N[x] = N(x) \cup \{x\}$  is the closed neighbourhood of  $x$ .

**Definition 2.9**

The effective degree of a vertex  $u$  is defined to be sum of the weights of the effective edges incident of 'u' and is denoted by  $dE(u)$ .  $\sum_{v \in N(v)} \sigma(v)$  is called the neighbourhood degree of  $u$  and is denoted by  $dN(u)$ .

**Definition 2.10**

The minimum effective degree  $\delta_E(G) = \min\{dE(u) \mid u \in V(G)\}$  and the maximum effective degree  $\Delta_E(G) = \max\{dE(u) \mid u \in V(G)\}$ .

**Definition 2.11**

The effective edge degree of an edge  $e = uv$ , is defined to be  $d_E(e) = dE(u) + dE(v)$ .

The minimum edge effective degree and the maximum edge effective degree are  $\delta'_E(G) = \min\{d_E(e) \mid e \in X\}$  and  $\Delta'_E(G) = \max\{d_E(e) \mid e \in X\}$  respectively.

$N(e)$  is the set of all effective edges incident with the vertices of  $e$ .

In a similar way minimum neighbourhood degree and the maximum neighbourhood degree denoted by  $\delta'_N$  and  $\Delta'_N$  respectively can also be defined.

**Definition 2.12**

A fuzzy graph  $G = (\sigma, \mu)$  is said to be bipartite if the vertex set  $V$  can be partitioned into two non-empty sets  $V_1$  and  $V_2$  such that  $\mu(v_1v_2) = 0$  if  $v_1, v_2 \in V_1$  (or)  $v_1, v_2 \in V_2$ .

Further if  $\mu(uv) = \sigma(u) \wedge \sigma(v)$  for all  $u \in V_1$  and  $v \in V_2$  than  $G$  is called a complete bipartite graph and is denoted by  $K_{\sigma_1, \sigma_2}$  where  $\sigma_1$  and  $\sigma_2$  are, respectively, the restrictions of  $\sigma$  to  $V_1$  and  $V_2$ .

**3. INVERSE SPLIT EDGE DOMINATION IN FUZZY GRAPHS**

**Definition 3.1**

Let  $G = (\sigma, \mu)$  be a fuzzy graph on  $(V, X)$ . A subset  $S$  of  $X$  is said to be an edge domination set in  $G$  if for every edge in  $X-S$  is adjacent to atleast one effective edge in  $S$ .

The minimum fuzzy cardinality of an edge dominating set in  $G$  is called the edge domination number of  $G$  and it is denoted by  $\gamma'(G)$  or  $\gamma'$ .

**Definition 3.2**

Let  $G = (\sigma, \mu)$  be a fuzzy graph on  $(V, X)$ . A subset  $D$  of  $X$  is a minimal edge dominating set of a fuzzy graph  $G$ . If  $V - D$  contains an edge dominating set  $D'$  is called an inverse edge dominating set of  $G$  with respect to  $D$ .

The minimum fuzzy edge cardinality taken over all inverse edge dominating set of  $G$  is called the inverse edge domination number of the fuzzy graph  $G$  and it is denoted by  $\gamma'_I(G)$  or  $\gamma'_I$

**Definition 3.3**

Let  $G = (\sigma, \mu)$  be a fuzzy graph on  $(V, X)$ . A subset  $D$  of  $X$  is a minimal edge dominating set of a fuzzy graph  $G$ . If  $V - D$  contains an edge dominating set  $D'$  of  $G$  and  $\langle D' \rangle$  is disconnected is called an inverse split edge dominating set of  $G$  with respect to  $D$ .

The minimum fuzzy edge cardinality taken over all inverse connected edge dominating set of  $G$  is called the inverse connected edge domination number of the fuzzy graph  $G$  and it is denoted by  $\gamma'_{IS}(G)$  or  $\gamma'_{IS}$

**Remark 3.4**

It is clear that if  $G$  has atleast one edge, then  $0 \leq \gamma'_I(G) \leq q$ . However if a graph  $G$  has no effective edges, then  $\gamma'_I(G) = 0$

**Theorem 3.5**

For any fuzzy graph  $G$ ,  $\gamma'_I(G) \leq \gamma'_{IS}(G)$ .

**Theorem 3.6**

For any fuzzy graph  $G$ ,  $\gamma'_{IS}(G) \leq \gamma'_{IS}(H)$  where  $H$  is the spanning sub graph of  $G$ .

For the inverse split edge domination number  $\gamma'_{IS}(G)$ , the following theorem gives a Nordhaus – Gaddum type result.

**Theorem 3.7**

For any fuzzy graph  $G$ ,  $\gamma'_{IS} + \bar{\gamma}'_{IS} \leq 2q$ . where  $\gamma'_{IS}$  is the inverse split edge domination number of  $\bar{G}$  and equality holds if and only if  $0 < \mu(xy) < \sigma(x) \wedge \sigma(y)$  for all  $xy \in E$ .

**Proof.**

The inequality is trivial. Further  $\gamma'_{IS} = q$  if and only if  $\mu(xy) < \sigma(x) \wedge \sigma(y)$  for all  $xy \in E$  and  $\bar{\gamma}'_{IS} = q$  if and only if  $\sigma(x) \wedge \sigma(y) - \mu(xy) < \sigma(x) \wedge \sigma(y)$  for all  $xy \in E$  which is equivalent to  $\mu(xy) > 0$ . Hence,  $\gamma'_{IS} + \bar{\gamma}'_{IS} = 2q$  if and only if  $0 < \mu(xy) < \sigma(x) \wedge \sigma(y)$ .

**Definition 3.8**

An inverse split edge dominating set  $D$  of a fuzzy graph  $G$  is said to be minimal inverse split edge dominating set if no proper subset  $D$  is an inverse split edge dominating set of  $G$ .

**Theorem 3.9**

An inverse split edge dominating set  $D'$  is minimal if and only if for each edge  $e \in D'$ , one of the following two conditions holds.

- (a)  $N(e) \cap D' = \emptyset$
- (b) There exists an edge  $f \in X - D'$  such that  $N(f) \cap D' = \{e\}$  and  $f$  is an effective edge.

**Proof.**

Let  $D'$  be a minimal inverse split edge dominating set and  $e \in D'$ . Then  $D'_e = D' - \{e\}$  is not an inverse split edge dominating set and hence there exists  $f \in X - D'_e$  such that  $f$  is not dominated by any element of  $D'_e$ .

If  $f = e$  we get (a) and if  $f \neq e$  we get (b). The converse is obvious.

**Definition 3.10**

An edge  $e$  of a fuzzy graph  $G$  is said to be an isolated edge if no effective edges incident with the vertices of  $e$ .

Thus an isolated edge does not dominate any other edge in  $G$ .

**Theorem 3.11**

If  $G$  is a fuzzy graph without isolated edges then for every minimal inverse split edge dominating set  $D$ ,  $X-D$  is also an inverse split edge dominating set.

**Proof.**

Let  $f$  be any edge in  $D$ . Since  $G$  has no isolated edges, there is an edge  $c \in N(f)$ . It follows from theorem 3.8 that  $c \in X-D$ . thus every element of  $S$  is dominated by some element of  $X-D$ .

**Corollary 3.12**

For any fuzzy graph  $G$  without isolated edges  $\gamma'_{IS} \leq \frac{q}{2}$ .

**Proof.**

Any graph without isolated edges has two disjoint inverse split edge dominating sets and hence the result follows.

**Corollary 3.13**

Let  $G$  be a fuzzy graph such that both  $G$  and  $\bar{G}$  have no isolated edges. Then  $\gamma'_{IS} + \bar{\gamma}'_{IS} \leq q$ , where  $\bar{\gamma}'_{IS}$  is the split edge domination number of  $\bar{G}$ . Further equality holds if and only if  $\gamma'_{IS} = \bar{\gamma}'_{IS} = \frac{q}{2}$ .

**Theorem 3.14**

If  $G$  is a fuzzy graph without isolated edges then  $\frac{q}{\Delta'(G)+1} \geq \gamma'_{IS}(G)$ .

**Proof.**

Let  $D$  be an inverse split edge dominating set of  $G$

$$\text{Since, } |D| \Delta'(G) \leq \sum_{e \in D} d_E(e) = \sum_{e \in D} |N(e)|$$

$$\leq |\bigcup_{e \in D} N(e)|$$

$$\leq |E-D|$$

$$\leq q-|D|$$

$$\therefore |D| \Delta'(G) + |D| \leq q$$

$$\text{Thus } \gamma'_{IS}(G) \leq \frac{q}{\Delta'(G)+1}$$

**Theorem 3.15**

For any fuzzy graph  $\gamma'_{IS}(G) \geq q- \Delta'(G)$ .

**Definition 3.16**

Let  $G$  be a fuzzy graph without isolated edges. A total inverse edge dominating set  $D$  of a fuzzy graph  $G$  is set of fuzzy edges of  $X$  for which each  $e \in X$  is incident with edges of  $D$ , i.e.,  $N[D] = X$ .

The minimum fuzzy cardinality of a total edge dominating set is called the total edge domination number of  $G$  and is denoted by  $\gamma'_t(G)$ .

**Theorem 3.17**

If a fuzzy graph  $G$  has no isolated edges then  $\gamma'_{IS}(G) \leq \gamma'_t(G)$ .

**Theorem 3.18**

For any fuzzy graph  $\frac{q}{\Delta'(G)} \geq \gamma'_t(G)$ .

**Proof.**

Let  $D$  be a total edge dominating set with minimum number of fuzzy edge cardinality. Then every edge in  $D$  is adjacent to atleast  $\Delta'(G)$  fuzzy edge cardinality, therefore,

$$|D| \Delta'(G) \leq q. \text{ Hence } \frac{q}{\Delta'(G)} \geq \gamma'(G).$$

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